**Synopsis**

# EXPLORING THE EFFECT OF AMINO ACIDS ON SULFATE FAMILY CRYSTALS FOR NONLINEAR OPTICAL DEVICE APPLICATIONS

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## 1. Introduction:

In materials science the fundamental knowledge of single crystal plays major role in understanding the nature of the crystal also the unique orderly arrangement of the particles in unit cell offers vital traits to the crystal [1-3]. The single crystals have applications in diverse fields which extends from making of ornaments to development of semiconductor, opto-electronics and NLO devices. Looking at the technological point of view the optical, electrical, physical and mechanical traits of any crystal are crucial for designing optical modulators, optical switching, frequency shifting, terahertz wave generators, optical communication and optical data storage devices [1-6]. To explore the suitability of specific crystal for desired application researcher has to hunt for the ideal crystal and crystal can belong to one of the class of material which accompanies organic, inorganic and semi-organic materials. Crystal of each class (i.e. organic, inorganic and semi-organic) has its advantage and disadvantage however our investigation is targeted to develop the inorganic crystals. The uniqueness of inorganic crystals includes high environmental, mechanical and thermal stability at the same time they have the capability to transmit the optical signal in UV and deep UV region. The large variety of technologically vital inorganic crystals developed in recent past are AZSH, KZSH, $LiNbO_3$, $KNbO_3$, KDP, ADP, DKDP, KTP, CuS, KAS, etc [7-12]. The scrupulous literature analysis reveals that the development of crystals can be achieved by various approaches as discussed below,

(A) Designing novel chemical combination of crystal

(B) Optimizing the growth parameters of crystal

(C) Improving inherent traits of crystal by adding impurity

It is evident that the most effective approach for developing a potential crystal is to tailor the properties of crystal by adding the definitive quantity of impurity. In order to obtain dominating NLO crystals, the amino acids play a vital role as they possess the donor amine ($-NH_2$) and acceptor carboxylic (-COOH) group which enable high and fast intermolecular charge transfer. The amino acid also offer least absorption over wide range of optical spectrum in addition allows the flexibility in molecular alignment of the host crystal. The amino acid like arginine, lysine, L-theorine, L-alanine, γ-glycine, valine, threonine, proline, etc.

**2. Review of Literature:**

The globally vital NLO crystals utilized in photonics and optoelectronic industries are potassium dihydrogen phosphate, ammonium dihydrogen phosphate, lithium niobate, barium borate and many more [13-19]. The fundamental characteristic properties such as nucleation kinetics of sulphamic acid crystal have been investigated by various researchers [20-22]. The study and unidirectional bulk crystal growth of sulphamic acid by Shankaranarayana-Ramasamy method has been achieved by Pandian et al [23]. The potassium acid phthalate (KAP) crystal has been grown by slow solvent and unidirectional Shankaranarayana-Ramasamy method by Balamurugan et al [24]. The detail analysis on ammonium dihydrogen phosphate crystal has been investigated by many researchers [25-27]. The doping effect of $Ce^{3+}$ metallic impurity on bulk growth and distinct properties of sulphamic acid crystal has been investigated by Brahmaji et al [27].The structural, morphological, optical and thermal properties of gadolinium doped sulphamic acid crystal have been extensively studied and reported by Kannan et al [28]. The influence of thiourea on morphology, structural, optical transparency, thermal and second harmonic generation (SHG) efficiency of sulphamic acid crystal has been investigated by

Kannan et al [28]. The influence of urea on crystalline perfection, spectral and UV-visible transparency of sulphamic acid has been successfully explored by Rajalakshmi et al [30]. The effect of lanthum on crystal structure, morphology, thermal, linear and nonlinear optical properties of sulphamic acid crystal has been investigated by Kannan et al [31]. The effect of Co2+ on spectral, structural, linear optical, dielectric, microhardness and thermal properties of ADP crystal has been examined by Rajesh et al [32]. The influence of $Ni^{2+}$ on growth, optical, dielectric and thermal properties of ADP crystal has been evaluated by Rajesh et al [33]. The effect of L-arginine and L-valine on spectral, optical, thermal and mechanical properties of KAP crystal has been investigated by Prakash et al [34]. Influnce of rare earth element Sm+ on various properties of KAP crystal has been investigated by Sudhahar et al [35]. The Influence of different mole concentration of L-lysine on various properties of KAP crystal has been extensively studied by Thilagavathy et al [36]. The effect of sodium metasilicate ($Na_2SiO_3$) on ADP crystal has been investigated by Anis et al [37]. The effect of L-ascorbic acid on optical traits of copper sulfate has been investigated by Ramteke et al [11]. The optical analysis of potassium aluminium sulfate crystal has been studied in detail by Ramteke et al [12]. Influence of formic acid on optical properties of KDP crystal has been investigated by Anis et al [38]. Effect of L-valine on optical, electrical and mechanical traits of ADP crystal has been reported by Shaikh et al [39]. Doping effect of L-alanine and L-lysine on linear optical traits of ADP crystal has been determined by Shaikh et al [40]. Impact of glycine on luminescence and third order NLO traits of ADP crystal has been reported by Shaikh et al [41]. Second and third order NLO traits of Oxalic acid and maelic acid doped KDP crystal has been explored by Anis et al [42]. Various properties of L-cystine doped KDP crystal has been thoroughly studied studied by Shaikh et al [42]. Impact of slycylic acid on KDP crystal has been investigated by Baig et al [43].

Effect of citric acid on optical and electrical properties of KDP crystal has been evaluated by Anis et al [44]. Effect of tartaric acid on linear-nonlinear optical traits of KDP crystal has been investigated by Baig et al [45]. Investigated on citrulline doped KDP crystal has been accomplished by Shaik et al [46]. Luminescence, morphology and SHG efficiency of ADP crystal has been investigated in presence of tartaric acid by Ramteke et al [47].

In current era single crystals with excellent NLO response are prerequisite for applications in frontier technological fields for fabrication of photonic devices viz. optical switching, optical modulators, optical limiters, optical communication systems, laser systems and SHG transmission devices. A large variety of inorganic crystals are current grown and investigated throughout the world. However the scope of improvement in linear-nonlinear optical, dielectric, thermal and mechanical properties of given inorganic crystal can be achieved by (a) optimizing the growth conditions and (b) doping a suitable external impurity. It is interesting to know that the tailoring of material properties through doping is found to be the most exclusive and effective technique. Thus in such case a organic additive (amino acids, carboxylic acid, etc) can play a vital role as they possess donor-acceptor channel for charge transfer and inherent nonlinear response. The organic additives can thus be the potential dopant in proposed crystal in order to raise the overall performance of host crystals.

**3.Objectives of Research/ Proposed Hypothesis:**

1. Amino acids are expected to improve structural morphology of host crystals.

2. Amino acids are expected to improve optical properties of host crystals.

3. Amino acids are expected to improve nonlinear optical properties of host crystals.

Aims and Objectives**:**

I. Single crystals of undoped and organic additives doped materials [Copper Sulfate ($CuSO_4.5H_2O$), Potassium Aluminium Sulfate ($KAl(SO_4).12H_2O$), Nickel(II) Sulfate ($NiSO_4(H_2O)_6$)] will be grown by slow solvent evaporation technique.

II. The identified suitable amino acid (Alanine, Valine, Proline) will be used as dopant for proposed host crystals and investigate its effect on different properties.

III. Characterization techniques namely spectroscopic (energy dispersive spectroscopy (EDS) or Fourier transform infrared (FT-IR) analysis), structural (Single crystal XRD or powder XRD), optical (UV-visible and Z-scan analysis and Laser damage threshold), electrical (dielectric study or photoconductivity study), mechanical (Vicker's microhardness analysis, Etching analysis) and thermal (thermogravimetric analysis or differential thermal analysis or differential scanning calorimetry) will be employed to perform comparative study on grown crystals.

IV. The results will be analyzed and the possible applications of the grown crystals will be discussed for NLO devices.

**4.Methodology to be Adopted**

Crystal growth by Slow Solvent Evaporation Method:

The research grade high purity salts of host material i.e. Copper Sulfate and Potassium Aluminium Sulfate and Nickel Sulfate of AR grade will be purchased and the homogeneous solution of these materials will be prepared in distilled water. The precise quantity of the organic dopant will be measured using the digital weighing balance. The dopant will be gradually added to the homogeneous solution of host material with constant stirring to allow homogeneous mixing of the material. The doped solution will be filtered and kept for slow solvent evaporation at suitable temperature in a vibration free constant temperature water bath. In few days the seed crystals will be harvested and further used for bulk single crystal growth.

Characterization:

- The structural analysis will be done using single crystal XRD or powder XRD analysis.
- The quantitative and qualitative analysis will be done using FT-IR or EDX analysis, etc.
- Optical analysis includes UV-visible studies, Z-scan studies and laser damage threshold, etc.
- Thermal studies will be done using thermogravimetric or differential thermal analysis.
- Electrical properties will be examined by dielectric or photoconductivity studies.
- Mechanical properties will be studied using Vickers microhardness test or etching analysis.
- The obtained results will be evaluated to explore the device applications of grown crystals and publish it in reputed journals.

## 5.IMPORTANCE OF STUDY / SOCIETY APPLICATION

National Status (Focus on India)

In India, the study of nonlinear optical materials, particularly amino acid-doped sulphate crystals, is gaining importance in both academic and applied research sectors. The Indian government and several research funding agencies, such as the Department of Science and Technology (DST), support initiatives in advanced materials for photonic devices, with a specific focus on crystal growth and NLO properties.

International Status

Globally, research in nonlinear optical materials, especially those based on crystals, has been expanding due to the growing demand for devices in telecommunications, medical imaging, and industrial applications. Several countries have made significant advancements in both the theoretical and experimental aspects of these materials

**Broad applications of optical crystal:**

- Optical Switching
- Optical Modulators
- Optical Limiters
- Optical Communincation System
- Laser System
- SHG Transmission Devices
- Optoelectronics
- Photodetectors

## 6.SIGNIFICANCE OF STUDY

- The single crystals with improved optical, electrical, mechanical, thermal and nonlinear optical properties will introduce new dimensions in technological development of photonics industries. Hence in proposed work, we expect to grow a potential NLO crystal with excellent linear-nonlinear optical, dielectric, physical and thermal properties at affordable commercial value which will be made available for applications in multidisciplinary field of engineering.
- These crystals will be investigated to explore the credibility for distinct NLO facilitated device applications such as photonics, microelectronics, optoelectronics, electro-optic modulators, detectors, actuators, SHG transmission devices and laser systems.
- The good quality crystals will be grown that highly reduce the wastage of material which is imperative factor while processing and designing the mechanically rigid optical elements of laser systems.

**7.Chapter Scheme**

**Chapter 1.** Introduction

**Chapter 2.** Characterization Techniques

**Chapter 3.** Comparative investigation of amino acid doped Copper sulfate/Potassium Aluminium Sulfate/Nickel sulfate crystal

**Chapter 4.** Comparative investigation of amino acid doped Copper sulfate/Potassium Aluminium Sulfate/Nickel sulfate crystal

**Chapter 5.** Comparative investigation of amino acid doped Copper sulfate/Potassium Aluminium Sulfate/Nickel sulfate crystal

**Chapter 6.** Summary and Future scope

**Tentative Scheme:**

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|---|---|
| First Year | Literature Review and chemical purchasing material synthesis**.** |
| Second Year | Crystal Growth |
| Third Year | Characterization |
| Fourth Year | Interpretation of Result |
| Last Six Months | Thesis Writing |

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